

**Review of the  
U.S. Department of Defense  
Air, Space, and Supporting Information Systems  
Science and Technology Program**

Committee on Review of the U.S. Department of Defense  
Air and Space Systems Science and Technology Program

Division on Engineering and Physical Sciences  
National Research Council

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## **Executive Summary**

### **TASK AND APPROACH**

In November 1999, in response to congressional direction to the Secretary of Defense appearing in Section 214 of the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999 (P.L. 105-261), the Deputy Under Secretary of Defense for Science and Technology (DUSD (S&T)) requested that the National Research Council (NRC) conduct a study on the technology base of the Department of Defense. The statement of task for this study was as follows:

The NRC will conduct a study that

- a) builds upon projections made by the DoD, as included in planning documents and through dialogue with DoD principals, to define and project an “adequate technology base” in the areas of air and space systems, and in the supporting information technology, in the 2010 to 2020 timeframe,
- b) determines in a qualitative sense the level of investment required to attain/maintain the technology base defined above (i.e., will current S&T budgetary projections be sufficient to attain/maintain this base), and
- c) examines the academic degree requirements and numbers of members of the services to maintain adequate in-house research in areas where industry does not provide support, and management oversight expertise in areas of research where industry is performing sufficient research.

Congress was particularly concerned about the declining Air Force investment in science and technology (S&T) since the end of the Cold War and about continuing reductions in the number of Air Force S&T personnel.

To conduct the study, the NRC established a committee of recognized experts in the areas of air, space, and information systems; personnel; resources; and defense S&T. In accordance with the statement of task, the Committee on Review of the U.S. Department of Defense Air and Space Systems Science and Technology Program met with U.S. Department of Defense (DoD) principals, reviewed DoD S&T planning

documents, and examined other studies concerned with DoD S&T. Although other service and defense research agency S&T programs include some air and space systems-related investments, it was clear from Section 214 and from discussions with congressional representatives that the focus of Congress's concern was the Air Force. The study committee thus focused its attention on Air Force S&T.

The request to determine "in a qualitative sense the level of investment required" suggested to the committee that the study's sponsor recognized the inherent difficulty of making any hard and fast recommendations on level of investment and therefore wanted the committee to use its best judgment in recommending an appropriate level of investment to secure an adequate technology base for DoD. Based on committee members' knowledge gained from their extensive experience with DoD and Air Force S&T and on the information reviewed during the study, the conclusions and recommendations presented in this report reflect the committee's qualitative rationale and collective judgment.

## **FINDINGS**

### **DoD Investment in S&T for Air and Space**

The DoD budget today is about 25 percent lower in real terms than at the end of the Cold War.<sup>1</sup> This reduction reflects attempts to realize a post-Cold War peace dividend and to deal with federal budget deficits in the 1990s. The Air Force budget is down even more over the same period, about 32 percent in real terms. For both DoD and the Air Force, budgets have been reduced in all major categories, including procurement, operations and maintenance, military personnel, and research, development, test, and evaluation (RDT&E), of which S&T is a part. The overall DoD S&T investment also shrank during the 1990s; however, it grew during FY00 and FY01 so that by FY01 it was about 2 percent greater, in real terms, than it was at the end of the Cold War. This increase in the DoD S&T investment did not come at the expense of other important defense needs. S&T now makes up only 3 percent of the total defense budget.

The trend at DoD toward greater investment in S&T is reflected in Army, Navy, and defense research agency investments in S&T, which have risen between 17 and 47 percent in real terms since FY89. The sole exception is the Air Force, whose real S&T investment is down by 46 percent. As a percentage of its total budget between FY89 and FY01, Air Force funding for S&T fell from about 2.2 percent to about 1.7 percent.

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<sup>1</sup>The terms "real dollars" and "constant dollars" refer to dollar amounts expressed in terms of their equivalent values in some base year. Expressing monetary values in these terms allows comparison of dollar amounts from different years that take into account the effects of inflation. The term "current dollars" refers to dollar amounts expressed in terms of their actual values in the years in which they are used. Comparing current-dollar amounts from different years does not take into account the effects of inflation and can be misleading. For dollar amounts given in this report, the reader is advised to note whether they are expressed in real/constant dollars or current dollars.

The Air Force has been under increasing financial stress since the Cold War ended. Operational requirements and tempo have increased, not fallen. Operations in the Gulf War, Bosnia, Kosovo, and the Northern and Southern Watch over Iraq have strained Air Force resources. Modernization programs, such as those for the F-22 and the Joint Strike Fighter, have required large outlays and will require even more resources as those programs enter production. At the same time, in what has been called a "death spiral," aging air and space systems are becoming more and more expensive to maintain and operate, leaving little money to cover the cost of their replacements. Under these conditions, it is not surprising that the Air Force has tried to find or divert money from every possible source, including its S&T investment, to pay these expenses.

Given this financial stress and the collapse of the Soviet Union, it could be argued that the need for Air Force investment in S&T has diminished and that the Air Force could thus afford to reduce that investment. The committee believes, however, that such reasoning does not take into account the changing nature of the global threat and the S&T challenges it presents. Although the Cold War impetus for the development of some advanced systems has diminished, continued S&T investment is still necessary, both to support advanced systems and to extend the lifetimes of aging systems until new systems can replace them. A new operational concept calling for rapid deployment and reduced dependence on overseas bases for force projection will require new technologies. The threats posed by the rapid spread of information technologies and the possible acquisition of weapons of mass destruction by international terrorist groups or nations that cannot otherwise afford large armed forces will require technological solutions. Accordingly, the committee believes that the Air Force, instead of reducing S&T investment, would have been better served by reorienting its existing investments and possibly increasing them in some areas to deal with threats that have arisen since the Cold War.

A key factor in Air Force S&T investment decisions is the effectiveness of S&T representation and advocacy at the corporate policy and decision-making level of the Air Force. Currently, the highest S&T-dedicated military position in the Air Force is the 2-star Air Force Research Laboratory (AFRL) commander position at Wright-Patterson AFB near Dayton, Ohio. The AFRL commander reports directly to a general (4-star), the commander of the Air Force Materiel Command (AFMC), of which AFRL is a part. AFMC headquarters is also located at Wright-Patterson. The AFMC commander's responsibilities are very broad, including the programs at four product centers, five air logistics centers, three test centers, and two major specialized centers, in addition to AFRL. The AFRL commander is also dual-hatted as the Air Force technology executive officer and as such reports as well to the Assistant Secretary of the Air Force for Acquisition, whose office is in the Pentagon.

The strength of S&T representation in the Air Force is weakened by the relatively small size of the S&T program compared with the Air Force's total program and compared with the broad scope of responsibilities held by the assistant secretary for acquisition and the AFMC commander. The relatively small size of the S&T investment affects perceptions of its value and the amount of attention paid to it. The Assistant Secretary of the Air Force for Acquisition is responsible for representing this S&T investment and is a member of the Air Force Council. However, he is also responsible for representing all Air Force acquisition programs, which constitute the "D" part of the

RDT&E investment and are much larger combined than the S&T program. The broad scope of responsibilities of the AFMC commander and the Assistant Secretary of the Air Force for Acquisition, combined with the relatively small size of the S&T program, can prevent effective advocacy for Air Force S&T at the corporate policy and decision-making level of the Air Force. The Air Force itself has recognized this problem and has recently taken actions to increase the level of S&T advocacy within the Air Force.

### Air and Space Systems

Many challenges currently face air systems S&T. Unmanned air vehicles, ranging in size from micro air vehicles to high-altitude, long-endurance platforms, require research in planning and decision-making algorithms, onboard image processing, and software-based systems integration. Highly maneuverable unmanned combat air vehicles require research in materials, structures, and aerodynamics. Hypervelocity weapon systems to provide global time-critical strike capability and strike capability against deeply buried targets require research in propulsion and guidance and control. Although the Air Force recognizes these needs, it is not investing in air systems S&T at the level necessary to meet them. At the start of the 21st century, the Air Force air systems S&T budget was less than half its level only 10 years earlier. Moreover, a large part of the remaining investment is constrained by Office of the Secretary of Defense (OSD) mandates. Finally, the Air Force has diverted part of its air systems S&T investment to increase its investment in space systems S&T.

There is substantial agreement in the U.S. national security community that, as other developed and developing nations have increased their capabilities to use space not only for peaceful purposes but also to threaten the United States or its vital interests, so also has the need increased for the U.S. military to patrol, protect, and use U.S. space assets. DoD and the Air Force recognize this need, as well as the need for increased research in space technologies. Nevertheless, their increased emphasis on space is not reflected in the Air Force's current S&T investments.

The committee found that the Air Force does, indeed, plan to double the percentage of its total S&T investment that is oriented toward space. However, this does not necessarily mean that the space S&T program is being doubled or even significantly changed. Looking at the numbers shows that a large part of the increase in the Air Force space S&T investment appears to be due to the Air Force's transfer of the relatively large Space-Based Laser and Discoverer II space-based radar programs, previously considered to be demonstration/validation programs, into the S&T appropriation. If this accounting change is set aside, the Air Force's planned space S&T investment will be about the same five years from now as it is today.

OSD continues to rely on the Air Force for the bulk of the department's space S&T investment. However, the Air Force is not the only service affected by the growing space threat. DoD space policy recognizes that this is a department-wide concern and a defense arena that should be emphasized throughout the department. Therefore, OSD should help the Air Force increase its space S&T investment by providing additional

S&T funding; moreover, OSD should increase the non-Air Force DoD space S&T investment as well.

### **Supporting Information Systems**

In recent years, the Joint Chiefs of Staff and the services have recognized information systems technology as an impetus for the revolution in military affairs and as a key enabler of their visions for the future. Information systems have become pervasive throughout the military. They are changing the equations of warfighting and are replacing sheer mass, which can be very expensive and difficult to apply in some situations, with equal or greater lethality and survivability achieved by greater speed, deeper and wider knowledge, increased precision, and tighter control.

Information systems are also pervasive in civilian society. On a personal level, almost everyone has some familiarity with information technology through their use of personal computers at work and at home, the Internet, and electronic commerce. Information systems technology is one of the most conspicuous aspects of the U.S. economy and, at a trillion dollars per year, the commercial, non-DoD investment in information technology is a significant driver of the U.S. economy. But the rapid spread of information technology is more than just a U.S. phenomenon. The use of information technology is proliferating around the globe, providing a basis for global technological and economic development and increasing connectivity within and between nations.

At the same time, however, the rapid spread of information technology is increasing the global threat because it can provide to other militaries the same power that it gives to the U.S. military. As dependence on information systems increases, societies also become more vulnerable to attack. Information systems can also support an asymmetric threat. Potentially hostile nations that cannot afford a large military force can afford today's advanced information systems, as can terrorist groups. With these technologies, access to the world through global connectivity, and hostile intent, such adversaries can cause great harm at low cost.

To deal with this accelerating threat, DoD needs to have a strong information systems S&T program that includes leveraging commercial advances where possible and investing in DoD-unique S&T. The annual trillion-dollar commercial investment in information technology is three orders of magnitude larger than DoD's billion-dollar budget for information systems technology. DoD needs to be prepared to take maximum advantage of these commercial advances. At the same time, however, DoD cannot forego its own investment in information systems S&T. Commercial hardware is normally not rugged enough for military use. Commercial software is frequently not reliable enough to use for mission-critical systems nor secure enough against determined adversaries. Commercial technology also spreads rapidly, which eliminates military advantages.

DoD information systems S&T should focus on computing and software technologies for high-performance, software-intensive DoD systems; seamless communications technologies to interconnect command echelons, services, and allies worldwide; decision-making technologies to conduct joint mission planning, rehearsal,

execution monitoring, battlefield visualization, and situational assessment; information assurance technologies to protect information and information systems; and modeling and simulation technologies that support all of these areas and the development of other technologies. Thus it is important for DoD to invest in the long-term basic research that the near-term, market-driven commercial sector does not find profitable. DoD also needs to invest in the applied research and advanced technology development required to move DoD and leveraged commercial advances into warfighters' hands as quickly as possible. The pervasiveness of information systems in military systems and in visions for future warfighting and the accelerating threat information technology poses require that DoD have a strong information systems S&T program.

The committee found the opposite to be the case, however, in its review of the Air Force S&T investment. Since at least the mid-1990s, the Air Force S&T investment in information systems has declined steadily, despite recurring annual plans to increase it.

At roughly \$2.5 million per year, the Air Force investment in in-house basic research for information systems is not enough to ensure support for real advances in in-house projects or to maintain the scientific expertise of the in-house workforce. The Air Force budget for applied research and advanced technology development in information systems accounts for only about 5 percent of the total Air Force S&T budget. Although the Air Force investment is supplemented by larger amounts of funding for information systems development that the Air Force manages for the Defense Advanced Research Projects Agency (DARPA) and other agencies, Air Force funding covers only in-house operating expenses and is not sufficient to pay for the transitioning of DARPA and other agency technology advances into Air Force systems. The committee believes that the Air Force investment in information systems S&T is insufficient to meet emerging threats and to satisfy the Air Force's current visions for future warfighting.

### **Air Force S&T Workforce**

Many studies have been done through the years on the health of government S&T laboratories, and all of them have concluded that the government needs to maintain a strong internal competence in research and development (see Appendix D). These studies have also noted quality problems in government laboratories and have recommended actions to solve these problems. Very recent studies by the Defense Science Board and the Air Force chief scientist continue this trend of expressing concerns about the quality and retention of DoD and Air Force technical personnel and proposing solutions. The NRC study committee found these concerns to be valid.

As the defense budget shrank after the Cold War, so did the number of Air Force personnel, including S&T personnel. In light of the need to maintain DoD's technology base in air, space, and supporting information systems, current concerns about the decline in the Air Force's S&T workforce are justified. The Air Force can contract with academic and industry partners to conduct a large part of the research and development it needs, but some of this research needs to be done in-house to ensure that it is focused on

transitioning advances into Air Force systems and to strengthen and maintain the scientific and engineering expertise of the Air Force's technical workforce.

The need for additional S&T might not be a concern if the Air Force had scientists and engineers to spare. It does not. From 1996 to 2000, the percentage reduction in AFRL personnel was twice as large as for the Air Force as a whole. This steep decline in personnel, paired with the reduced Air Force S&T budgets, means that the Air Force is being forced to do more with less.

Finally, to conduct a high-quality S&T program, the services need to be able to retain and recruit the highest-quality personnel. As the Defense Science Board and Air Force chief scientist studies pointed out, the post-Cold War drawdown, the growing economy based on high technology, and Civil Service rules governing the management and recruiting of government personnel have combined so as to almost ensure that the highest-quality DoD S&T personnel are the first to be lost. To counter these problems, Congress has tried to help. For example, Section 246 of the 1999 National Defense Authorization Act (P.L. 105-261) provides for three-year pilot programs to revitalize the service laboratories by waiving many of the restrictions regarding personnel recruiting and hiring, as well as restrictions on the use of outside technical experts. The committee endorses approaches of this kind.

## OVERARCHING CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations reflect the common themes of the study as a whole. Specific conclusions and recommendations in each area are included in the body of the report.

### Investment in S&T

**Conclusion 1.** The committee believes that the reductions made by the Air Force to its S&T investment since the end of the Cold War did not take into account the changing nature of the global threat and the S&T challenges it presents. While the need for an Air Force S&T investment oriented to the Soviet threat was diminished at the end of the Cold War, the need for overall Air Force investment in S&T was not. The committee believes that the Air Force's current (FY01) investments in air, space, and information systems S&T are too low to meet the challenges being presented by new and emerging threats.

**Recommendation 1.** The Secretary of Defense and the Secretary of the Air Force should continue to increase the Air Force investment in science and technology (S&T) to reach one-and-a-half to two times its current (FY01) level. Investments in S&T for air, space, and information systems should all be increased. Increasing one by decreasing the others will not satisfy current S&T program shortcomings and may create new ones.

## **S&T Representation and Advocacy Within the Air Force**

**Conclusion 2.** The committee strongly believes that the Air Force needs authoritative, S&T-focused and dedicated representation and advocacy at the corporate policy and decision-making level of the Air Force to help make informed trade-offs and budget decisions. Without corporate-level understanding and consideration of the effects its S&T investment can have on the Air Force's future, the committee believes that the Air Force faces undue risk that its S&T investment will not provide the technologies and systems needed to meet future threats. The committee is encouraged by the actions that the Air Force has recently taken to increase the level of S&T advocacy in the Air Force and believes these actions can result in a stronger S&T program. Additional actions could make Air Force S&T even stronger.

**Recommendation 2.** In addition to the actions they have already taken, the Secretary and the Chief of Staff of the Air Force should continue to look for ways and take actions to further strengthen S&T representation and advocacy at the corporate policy and decision-making level of the Air Force. There are a number of options they can consider, including (1) formally designating the Air Force science and technology (S&T) program as a corporate program, (2) having the current AFRL commander/TEO position report directly to the Chief of Staff or be a member of the Air Force Council, and (3) establishing an Air Force Council member position (normally an assistant secretary or a 3-star deputy chief of staff) to be filled by a person in the Pentagon who is focused on, dedicated to, responsible for, and authorized to represent and advocate S&T within the Air Force, formulate Air Force S&T budgets, and participate in Air Force corporate policy and decision-making activities. The Air Force can also benefit from carefully examining the special roles accorded the Chief of Naval Research and the Office of Naval Research in the Department of the Navy to consider how these roles could be adapted to the AFRL commander/TEO and AFRL to strengthen Air Force S&T. These options or others the Air Force identifies can address remaining weaknesses in Air Force S&T representation and advocacy and build upon the recent successes of the Air Force.

## **S&T Workforce**

**Conclusion 3a.** The reductions in the Air Force's S&T workforce since the end of the Cold War and the rules governing the hiring, firing, and management of S&T workers have helped to undermine the quality and health of the Air Force's S&T program. They threaten the S&T program's ability to deliver the technologies, enable the strategies, and satisfy the visions of the future military.

**Conclusion 3b.** Personnel management rules threaten the quality of the Air Force's S&T program.

**Conclusion 3c.** The talents of DoD's technically educated officer corps are not being fully exploited, the benefits of locating uniformed personnel with their warfighter perspectives close to DoD S&T performers and S&T investment decision makers are being lost, and the number of officers throughout DoD who understand the importance of S&T to U.S. military superiority is decreasing.

**Recommendation 3a.** The Secretary of Defense should request that Congress extend the three-year pilot program for revitalizing the service laboratories (under Section 246 of the 1999 National Defense Authorization Act [P.L. 105-261]) by at least three years to allow laboratory programs to implement changes and evaluate the results. The Secretary of Defense, service secretaries, and service chiefs of staff should seize the opportunity that Congress created with Section 246 to improve the quality and health of their science and technology (S&T) workforces as much as possible. The services should take maximum advantage of the flexibility offered by Section 246 to try innovative approaches to managing their S&T workforces.

**Recommendation 3b.** The Secretary of Defense, service secretaries, and service chiefs of staff should work aggressively to improve the development and use of their military science and technology (S&T) workforce. Officers should be encouraged to carry out S&T assignments, which should be viewed positively during consideration for promotions. High-grade career-advancement opportunities for S&T officers should be made visible.

**Recommendation 3c.** The Secretary of Defense, service secretaries, and service chiefs of staff should implement the remedial actions proposed by previous reports. These actions include establishing personnel demonstration projects increase the presence of leading national (perhaps also international) non-Department of Defense (DoD) scientists and engineers in DoD laboratories through Intergovernmental Personnel Act assignments and alternative management and staffing approaches, such as government-owned, collaborator-assisted arrangements.

**Recommendation 3d.** The Secretary of Defense, service secretaries, and service chiefs of staff should work with Congress and with other agencies to enact targeted modifications to Civil Service rules that directly affect the quality and health of the science and technology workforce.